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Satellite-Observed Algae Blooms in China's Lake Taihu

During the spring of 2007, a massive blue-green algae (*Microcystis*) bloom broke out in Lake Taihu, one of the largest inland lakes in China. This freshwater lake is located in the Yangtze River delta (Figure 1), one of the world's most urbanized and heavily populated areas. The massive bloom event became an environmental crisis that prompted officials to cut tap water supply to several million residents in nearby Wuxi city in China's Jiangsu province. The outbreak, which the Chinese government identified as a major natural disaster, forced unprepared residents to rush to buy bottled water for their normal usage. This article presents results from an analysis of that event that demonstrate an application of satellite-derived imagery for inland lake water quality monitoring, assessment, and management.

MODIS-Aqua Observations

The Moderate Resolution Imaging Spectroradiometer (MODIS) on NASA's Aqua satellite provided synoptic observations of the entire bloom event. MODIS-Aqua data for Lake Taihu in the spring of 2007 were acquired and processed to produce aquatic optical and biological products using a recently developed shortwave infrared (SWIR) atmospheric correction algorithm [*Wang*, 2007; *Wang et al.*, 2007]. In particular, MODIS high spatial resolution data (0.25 and 0.5 kilometers), in addition to MODIS 1-kilometer spatial resolution data, were used for this study.

Lake Taihu contains consistently highly turbid waters [*Zhang et al.*, 2006], and the derivation of MODIS lake property data requires using the SWIR method, due to significant water-leaving radiance contributions (i.e., lake radiance contributions) at the near-infrared (NIR) bands. The two MODIS NIR bands, at 748 and 869 nanometers, have been used for making atmospheric corrections in generating the NASA standard ocean color products. However, standard MODIS ocean color data processing often fails to produce any valid products in very turbid waters, e.g., in Lake Taihu, due to an incorrect assumption and/or computation of the NIR water contributions. It has been demonstrated that the SWIR method can produce reasonable MODIS ocean color products in waters that are consistently highly turbid nearly all of the time, along China's eastern coastal region (e.g., regions near Hangzhou Bay, the Yangtze River estuary, and so forth) [*Wang et al.*, 2007].

Results and Discussion

During the 2007 bloom event in Lake Taihu, MODIS-Aqua acquired several clear-sky images capturing some important moments as the bloom evolved and developed. Figures 2 and 3 provide examples of MODIS-derived water optical and biological properties during the bloom event. MODIS-observed imagery of chlorophyll *a* concentration (chl *a*) [*O'Reilly et al.*, 1998] (Figures 2b and 2e) and normalized water-leaving radiance at 443 nanometers (nLw(443)) [*Gordon and Wang*, 1994] (Figures 2c and 2f) show the spatial variation of the lake's optical and biological properties before the peak (29 March 2007) and during the peak (7 May 2007) of the bloom event. For such complex turbid waters, there might be some uncertainty in the algorithm in deriving chl *a* values. Thus, we used chl *a* as an index for bloom indication. Also, we found that for these cases (Figures 2 and 3), aerosols present in the region were not strongly light absorbing.

The MODIS corresponding true-color images are shown in Figures 2a and 2d with the spatial resolution of 0.25 kilometers. The chl *a* and nLw(443) images were generated in 0.5-kilometer spatial resolution. In addition, for waters with and without contamination by the algae bloom in Lake Taihu (locations indicated in Figure 2e), Figure 3 provides the temporal variation (29 March to 8 June 2007) for chl *a* (bottom) and nLw(443) (top) derived from MODIS-Aqua measurements for the entire bloom event.

MODIS chl *a* and nLw(443) data (Figures 2 and 3) show that the algae bloom contamination in Meiliang Bay in Lake Taihu (see Figure 1 for location) started in the first week of April and peaked around 7 May, with the event ending at the beginning of June. Meiliang Bay is one of the main water supply sources for nearby Wuxi city, and was one of the regions where waters were considerably contaminated by the algae bloom. In fact, in waters adjacent to Wuxi city (at a location of 31.53°N, 120.19°E), the MODIS-derived chl *a* concentrations reached approximately 181 milligrams per cubic meter on 7 May and approximately 127 milligrams per cubic meter on 14 May. These were the only two MODIS-acquired clear-sky images around the time that the algae bloom contamination peaked (Figure 3). The algae bloom happened primarily in regions of Meiliang Bay, Gonghu Bay, and Zhushan Bay, as well as in the western region of Lake Taihu (Figure 2). During the event, chl *a* values for the uncontaminated waters, e.g., in central lake regions, were relatively low (Figure 3, bottom). Results in Figures 2 and 3 show that this algae bloom, with its dramatically elevated pigment concentrations, resulted in a significant drop of the MODIS-derived water-leaving radiance at the blue band (443 nanometers) because of the strong algae absorption at that wavelength [*Gordon and Morel*, 1983; *Roesler et al.*, 1989].

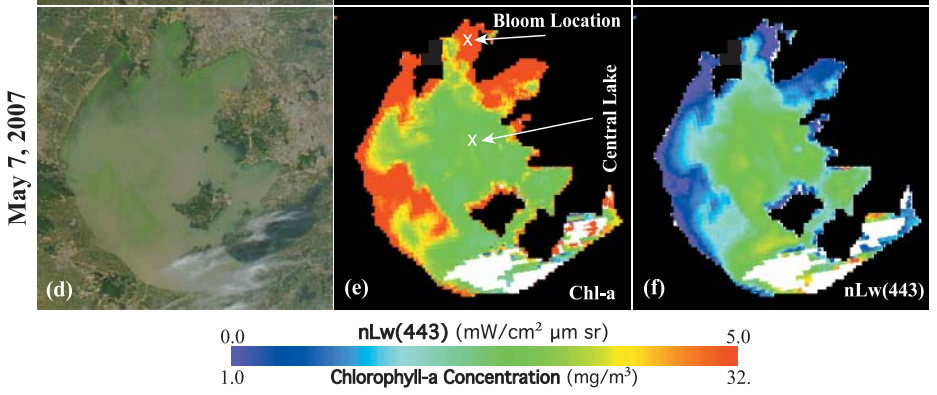

Fig. 2. MODIS-measured (a and d) true-color image, (b and e) derived chlorophyll a *(chl* a*) concentration, and (c and f) normalized water-leaving radiance at 443 nanometers (nLw(443)) for Lake Taihu.*

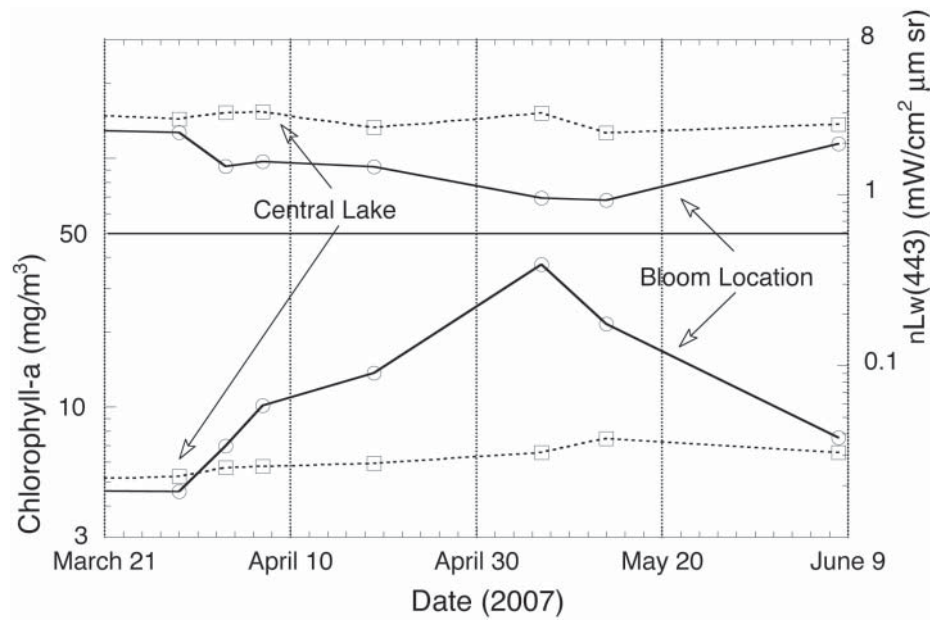

Fig. 3. MODIS-derived time series (29 March to 8 June 2007) for chlorophyll a *(chl* a*) (bottom portion and scale at left) and normalized water-leaving radiance at 443 nanometers (top portion and scale at right) (in 3 kilometer × 3 kilometer mean) for the algae bloom contaminated (solid curve) and noncontaminated (dotted curve) waters in the lake (locations indicated in Figure 2e).*

Monitoring Water Quality Using Remote Sensing Data

Our results demonstrate an important application for remote retrieval of inland water optical and biological properties using the SWIR atmospheric correction algorithm. Such satellite-derived data products can be useful monitoring and management tools, providing an improved understanding of optical, biological, and ecological processes and phenomena in inland lake waters. This work is responsive to needs identified in a March 2007 Global Earth Observation System of Systems (GEOSS) workshop on remote sensing of water quality (the workshop report is available at http://www.earthobservations.org/geoss_wa.shtml under "what is new?"). In particular, the satellite-derived imagery can be a significant contribution to an algae bloom warning system that will provide useful information for local governments to monitor and prepare for such events in advance.

Acknowledgments

The MODIS L1B data were obtained from the NASA Goddard Space Flight Center's MODIS Adaptive Processing System Web site. We thank NASA and the U.S. National Oceanic and Atmospheric Administration (NOAA) for providing research funding/grants for this work, and two anonymous reviewers for their useful comments. The views, opinions, and findings contained in this article are those of the authors and should

By M. Wang and W. Shi

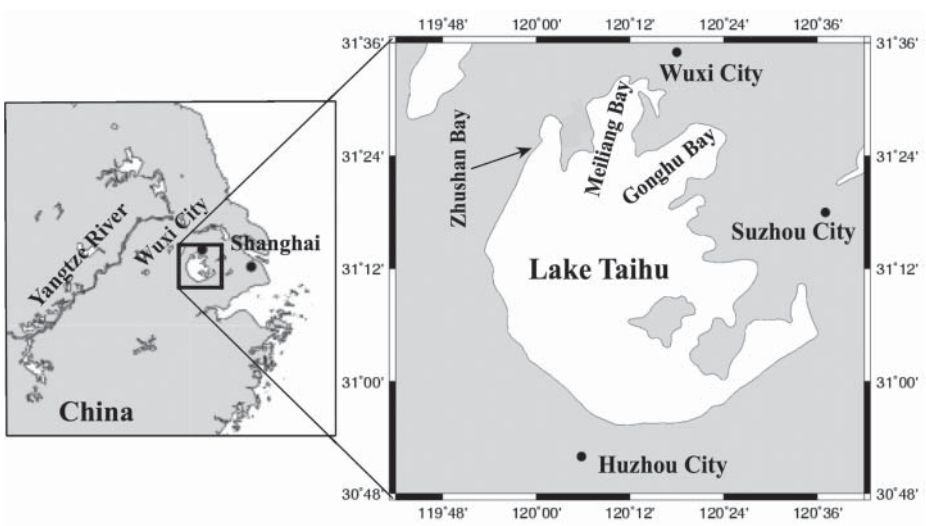

Fig. 1. Geolocations of Lake Taihu and Wuxi city in China.

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not be construed as an official NOAA or U.S. government position, policy, or decision.

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First Satellite Image of a Moving Pyroclastic Flow

Pyroclastic flows that emerge from the bases of collapsing eruption columns or lava domes are transient dynamic phenomena, rarely documented due to their very brief existence, which may be only minutes. Such flows are commonly reconstructed from their deposits. They have been photographed on the ground, but to the best of our knowledge, the pyroclastic flow described in this article is the first such flow in action that has been recorded on a satellite image. This provides an excellent opportunity to see the flow in action.

Mount Merapi, in Java, Indonesia, erupted several times in June 2006, and the 16 June IKONOS satellite imaging of the eruption coincided with the occurrence of a pyroclastic flow, a block-and-ash flow related to dome growth and collapse on the volcano. Figure 1 shows the entire mountain and surrounding area, including the dome on the steep southwestern face of the volcano. Figure 2, an enlargement of the outlined area in Figure 1, illustrates details of the pyroclastic flow. A strong wind blew the ash cloud away from the southern face of the volcano, improving the clarity of the image.

Figure 2 shows billowing clouds (mainly water vapor, gas, and ash) hugging the ground near the front and rising to a greater height farther back. The coarser material is confined to near the ground and the finer particles rise buoyantly toward the top, a process known as elutriation. This type of cloud is a coignimbrite ash cloud (also called a phoenix cloud), and fine material from it falls as a widespread deposit from the top of the hot pyroclastic flow.

In this picture, the ash cloud front is about 50 meters high and is marked by several bulges or billowing lobes that are separated by shearing from each other. The shears between the lobes are denser near the front, occurring along two directions, N80°E and N130°E, oblique to the valley. The pyroclastic flow, about 0.5 kilometers long and 0.25–0.5 kilometers wide, is moving down the head of the Gendol River valley on the southern slope of Merapi. The 1-meter resolution of the image displays the polylobate front of the flow and also the deposits left down-valley by earlier flows of this eruption. The pictured pyroclastic flow, confined to the left side of the valley, crossed a ridge created by the flow deposit of 14 June. The earlier flow reached as far as 6 kilometers down-valley (Figure 1). The poor sorting of the material (a mixed range of particle sizes), the scattered 1- to 4-meter boulders, and levees of pyroclastic deposits are all visible.

This satellite image, taken as IKONOS was above Merapi and when the flow had emerged from the volcano, provides a rare opportunity to study a pyroclastic flow in action.

Acknowledgments

The image that captured this event is taken from the archives of the Centre for Remote Imaging, Sensing and Processing (CRISP) at the National University of Singapore, where IKONOS images of Southeast Asia are stored. We acknowledge the role of Albert Ang Wu Chye of CRISP in processing the image.

—Soo Chin Liew, Centre for Remote Imaging, Sensing and Processing (CRISP), National University of Singapore, Singapore; Jean-Claude Thouret, Laboratoire Magmas et Volcans, Université Blaise-Pascal et Centre National de la Recherche Scientifique, Observatoire de Physique du Globe de Clermont-Ferrand et Institut de Recherche pour le Développement, Clermont-Ferrand, France; Avijit Gupta, Department of Geography, University of Leeds, Leeds, UK, and CRISP; E-mail: a.gupta@leeds.ac.uk; and Leong Keong Kwoh, CRISP

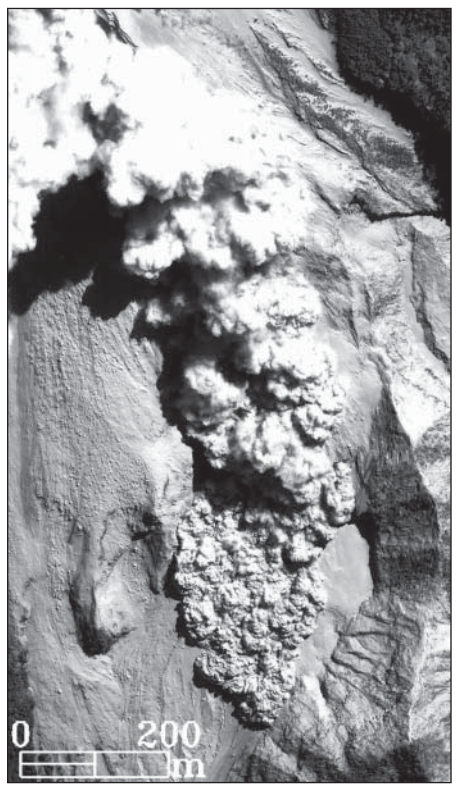


Fig. 2. Moving pyroclastic flow of 16 June 2006. Copyright CRISP. Reproduced with permission.

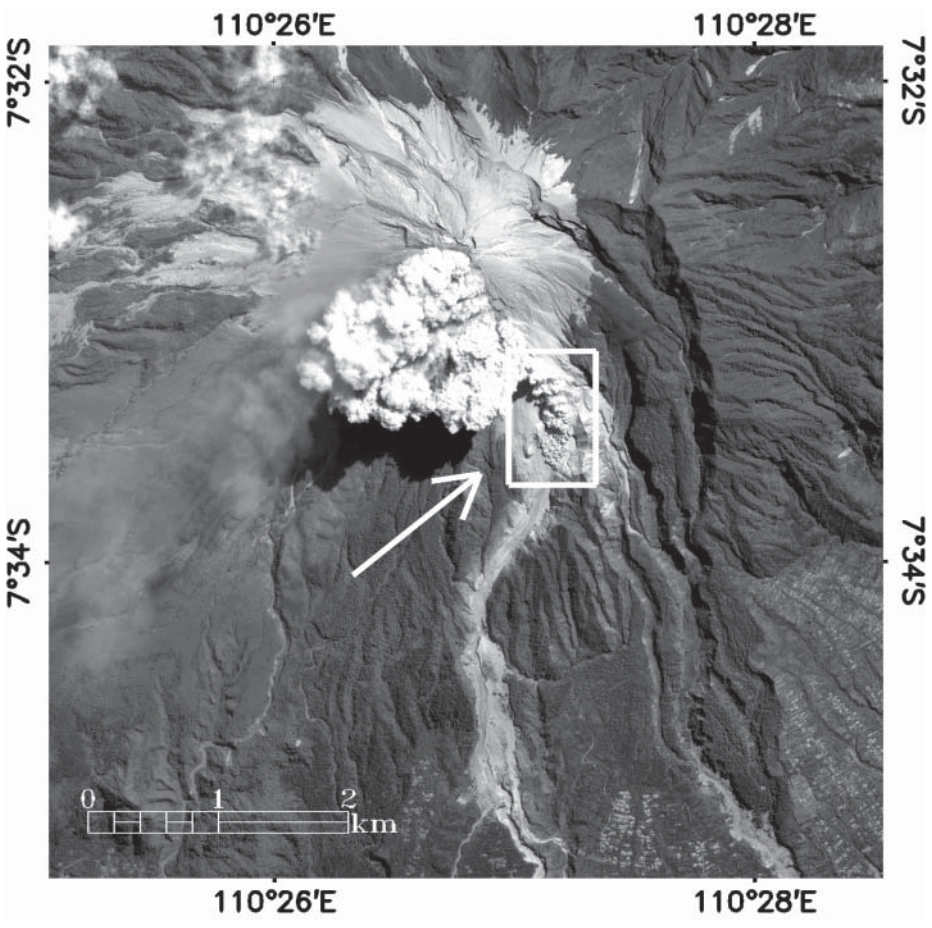


Fig. 1. Overview of Mount Merapi showing eruption clouds, the location of the pyroclastic flow of 16 June 2006 (Figure 2 is an enlargement of the outlined area), and previous pyroclastic and lahar deposits along the Gendol River valley. Note the locations of villages and rice fields to the southeast. Copyright CRISP. Reproduced with permission.

NEWS

Small Explosion From New Vent at Kilauea's Summit

At 0258 Hawaii-Aleutian Standard Time (HST) on 19 March 2008, a small explosion scattered altered and fresh lithic debris across a 40-hectare area at the summit of Kilauea volcano. This explosion, the first recorded there since 1924, issued from a vent about 35 meters wide along the east wall of Halema'uma'u Crater. Ballistic fragments—the largest measuring nearly 1 meter across—were propelled upward more than 70 meters onto the Halema'uma'u crater rim. Coarse ash and centimeter-size lithic debris covered part of Crater Rim Drive, and fine ash was deposited farther than 30 kilometers to the southwest.

Seismic tremor levels, which began rising steadily in early November 2007, reached nearly 5 times the background level by early 2008, coincident with ongoing deflation of the summit magma system as measured by tiltmeters. By late December, Kilauea summit sulfur dioxide (SO_2) emission rates had risen above normal rates of less than 400 tons per day, and the rates just prior to the March explosion were the highest recorded since regular measurements began, in 1979. Carbon dioxide emission rates, commonly associated with magma supply from depth, varied only slightly before the explosion. This suggests that shallow magmatic processes were responsible for the SO_2 increase.

On 11–12 March, tiltmeters recorded an episode of deflation and then inflation, followed by a swarm of shallow earthquakes at a depth of a few hundred meters near the Halema'uma'u east rim. Later on 12 March, a vigorous new fuming source appeared on the east wall of Halema'uma'u, pushing the SO_2 emission rate to nearly 1600 tons per day. By 15 March, the fuming vent exhibited an ever growing expanse of incandescence until the 19 March eruption.

Since then, the vent has produced a relentless ash-bearing plume with high SO_2 emission rates. The plume's appearance is white but has briefly turned to dusty brown as its lithic ash content increases.

On 23 March, Hawaiian Volcano Observatory (HVO) geologists began observing juvenile ejecta falling as Pele's hair, Pele's tears, and small clots of spatter on the rim of Halema'uma'u, indicating the rise of magma to near-surface depth. This lava, though small in volume, is the first erupted at Kilauea's summit since September 1982.

Seismic tremor levels and SO_2 emissions currently remain high at Kilauea's summit, and the magma system continues to feed the eruption on the volcano's east rift zone. Two additional smaller explosions have occurred, at 2308 HST on 9 April and at 0357 HST on 16 April. HVO is monitoring the ever changing activity. More information is available at http://hvo.wr.usgs.gov.

—David Wilson, Tamar Elias, Tim Orr, Matt Patrick, Jeff Sutton, and Don Swanson, U.S. Geological Survey Hawaiian Volcano Observatory, Hawaii National Park, Hawaii; E-mail: dwilson@usgs.gov

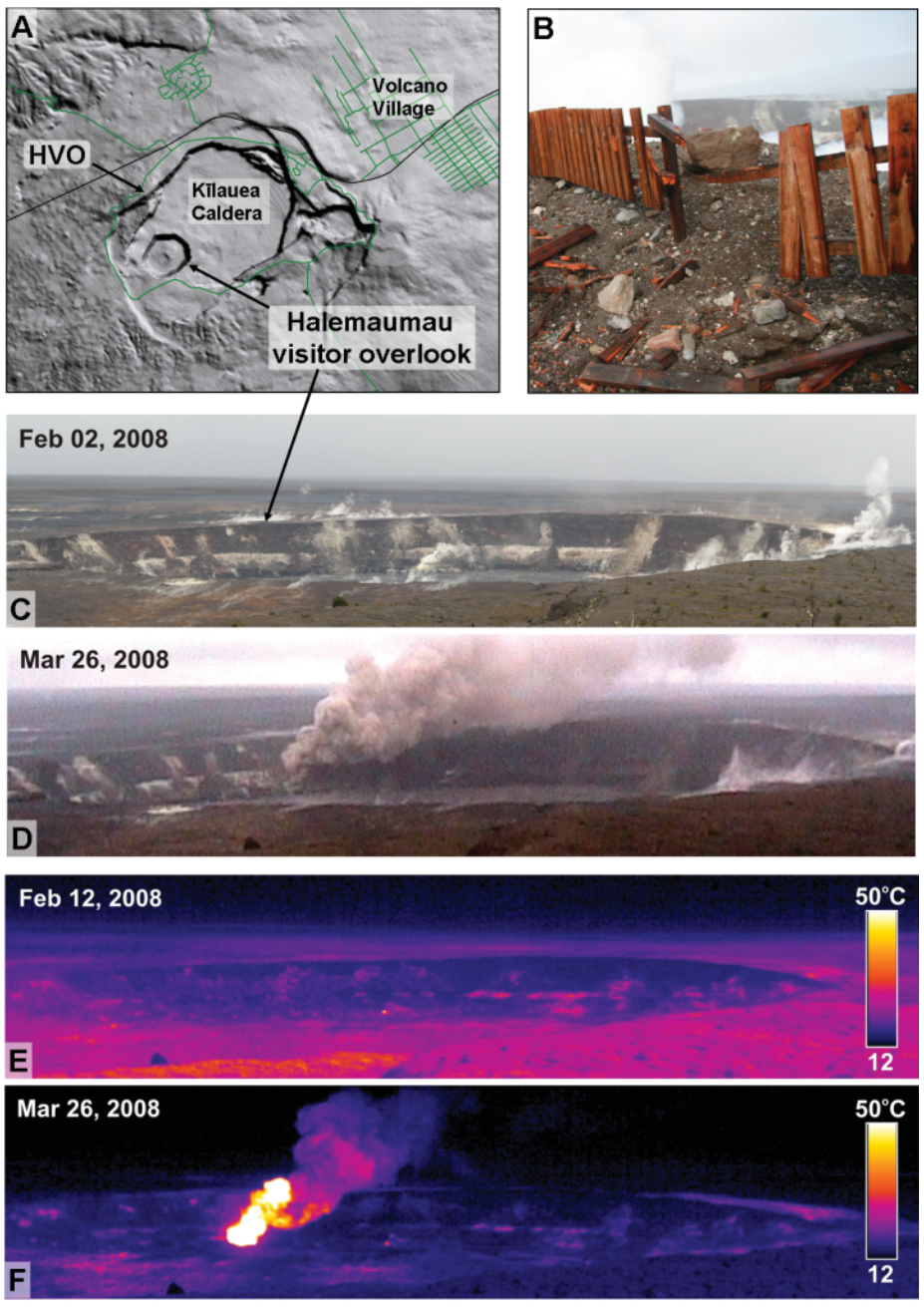


Fig. 1. Kilauea's summit area. (a) Overview map. (b) Fence at the Halema'uma'u visitors' overlook damaged by ballistic blocks. (c and d) Photographs of Halema'uma'u before and after explosion; view looks south from HVO. (e and f) Infrared imagery from the same vantage point. Temperature scale shows saturation at 50°C; hottest parts approach 500°C.

In Brief

U.S. interagency report on the Arctic A new report from the U.S. Interagency Arctic Research Policy Committee pinpoints where and how different federal agencies are collecting environmental data as part of the implementation of the Study of Environmental Arctic Change. The study aims to understand the rapidly changing Arctic, improve predictive capability, and identify appropriate adaptive responses to change. The report, "Arctic Observing Network (AON): Toward a U.S. Contribution to Pan-Arctic Observing," sets forth a plan to continue the observations in cooperation with local, state of Alaska, and international groups. The committee, led by the U.S. National Science Foundation (NSF), consists of more than 15 federal agencies, departments, and offices. The report is available at http://www.nsf.gov/pubs/2008/nsf0842/.

Cassini team issues atlas of Saturn's moon Dione Working with images from NASA's Cassini spacecraft, the Cassini Imaging Team released an atlas charting Saturn's fractured, 1125-kilometer-wide moon Dione on 20 May. "We used the 449 existing high-resolution Cassini images of Dione to produce a single carefully controlled global map," according to Thomas Roatsch, a planetary scientist from the Institute of Planetary Research at the German Aerospace Center (DLR), in Berlin. He said lower-resolution images taken by the Voyager spacecraft in 1981 helped with imaging the moon's north polar regions which are currently shrouded in seasonal darkness.

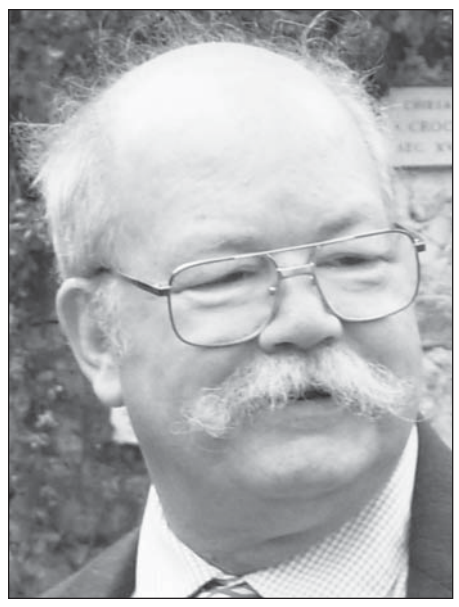
The imaging team previously released atlases of the geologically active moon Enceladus and the obscure outer moon Phoebe. Atlases of Iapetus and Tethys are next in line. The atlases allow scientists to easily find, and refer to, features of interest on the moons' surfaces. The atlases also serve as the basis for geologic interpretations, estimates of the ages of surface regions, and deciphering the processes that formed the moons' landscapes. More information is available at http://ciclops.org, http://www.nasa.gov/cassini, and http://saturn.jpl.nasa.gov. The Cassini-Huygens mission is a cooperative project of NASA, the European Space Agency, and the Italian Space Agency.

New University of Maryland research center A 14 May grand opening ceremony welcomed the first tenant to the University of Maryland's new research park, which will house several key weather and climate facilities. The first tenant, the Earth System Science Interdisciplinary Center (ESSIC), is a joint center between several University of Maryland departments and the Earth Sciences Directorate at NASA's Goddard Space Flight Center. The Joint Global Change Research Institute (JGCRI), which brings together the intersecting interests of the Pacific Northwest National Laboratory and the University of Maryland, will move into the building later this year. The U.S. National Oceanic and Atmospheric Administration's adjacent new building, expected to open in 2009, will house NOAA's Center for Weather and Climate Prediction, the U.S. focal point for generating ocean and atmospheric forecasts.

—Randy Showstack, Staff Writer

GEOPHYSICISTS

William R. Normark (1943–2008)



William R. Normark

William R. Normark passed away on 12 January 2008 at his home in Sunnyvale, Calif., after fighting cancer for nearly 8 years.

Bill was born in Seattle, Wash., but grew up a proud resident of western Wyoming. He moved to the West Coast to attend Stanford University in California for his undergraduate studies and headed to the Scripps Institution of Oceanography in La Jolla, Calif., for his Ph.D. While at Scripps, he started his pioneering studies on submarine fans using the newly developed remotely operated vehicle (ROV) Deep Tow under Fred Spiess's guidance. There, he also met his bride-to-be, Dorothy Jean "D.J." Detrich. After Bill received his Ph.D., he and D.J. spent 4 years at the University of Minnesota in Minneapolis before heading west again in 1974 where Bill began a distinguished career at the U.S. Geological Survey (USGS) in Menlo Park, Calif.

Bill was best known for his work on the character and depositional patterns of turbidite fan deposits, including research on the Navy, Laurentian, Monterey, Hueneme, and Amazon fans. This research took him to many different continents, where he had international collaborations with, among others, Emiliano Mutti (University of Parma, Italy) and Gian Gaspare Zuffa (University of Bologna, Italy), with whom Bill wrote influential papers on deepwater depositional systems. Notably, his long-continuing collaboration with David Piper of the Geological Survey of Canada (GSC) led to significant papers about the architecture, sediment type, and growth patterns of fan deposits, both ancient and modern.

Bill started his career with the USGS by building on his prior experience with remotely operated, deepwater mapping vehicles as well as his interest in, and knowledge of, depositional processes and the energy resource potential of modern submarine fans, which became a target of hydrocarbon exploration in recent years. Because of his deepwater mapping abilities, Bill was part of a geophysical research cruise in 1979 to the East Pacific Rise at 21°N, and he was in the deep-ocean submersible *Alvin* when the first-ever black smoker hydrothermal vents were discovered. Bill's dive on

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the *Alvin* was a chance opportunity: When another researcher scheduled for the dive was unable to participate, Bill felt incredibly lucky to do so. (For more information about the discovery, see F. N. Spiess et al., East Pacific Rise: Hot springs and geophysical experiments, *Science, 207,* 1421–1433, 1980.)

Soon after that *Alvin* cruise, in the early 1980s Bill led the USGS program on hydrothermal mineral deposits on ocean spreading ridges (primarily on the Juan de Fuca and Gorda ridges, approximately 200 kilometers off the Oregon-Washington coast) in collaboration with the U.S. National Oceanic and Atmospheric Administration, the Geological Survey of Canada, and the University of Hawai'i, among others. This project, which Bill undertook in addition to his ongoing primary research on depositional processes on continental margins and marine sedimentary environments, fostered the Geological Survey of Canada's hydrothermal mineral research program.

Among his many projects with the USGS was the Geological Long-Range Inclined Asdic (GLORIA) side-scan sonar effort to map the Hawaiian Islands. Bill and colleagues with the USGS Volcano Hazards Team identified gigantic submarine debris avalanches, which are some of the largest mass failures on Earth. The scale of these failures suggests major tsunami potential, an important threat to monitor off the active south flank of the Kilauea volcano on the Big Island of Hawaii. More recently, Bill was involved with high-resolution surveys of the California Continental Borderland basin to identify gas hydrates and natural oil and gas seeps. He also helped identify late Pleistocene flood deposits from the glacial Lake Missoula lying seaward of the mouth of the Columbia River.

Throughout his career, Bill was well known for his collaborative efforts with scientists within and outside his areas of expertise.

Between 1988 and 1996, he served as USGS associate chief geologist and then as acting regional geologist to coordinate facilities, programs, and personnel issues for the Western Region. During that time, Bill nonetheless continued to pursue his research activities. At the end of his managerial stint, and to his great satisfaction, Bill returned to a full slate of research activities and in particular helped assess earthquake hazards offshore southern California.

During his career with the USGS, Bill served on several Ocean Drilling Program (ODP) advisory panels, was the Joint Oceanographic Institutions/U.S. Science Advisory Committee Distinguished Lecturer for 1995–1996, and participated in ODP Leg 155 to study the Amazon fan. During much of his career, he also served on editorial boards of high-profile journals, including *Geology*, *Journal of Sedimentary Petrology* (now *Journal of Sedimentary Research*), *Marine Geodesy*, and *Giornale di Geologia*.

Bill was the primary author of more than 90 peer-reviewed papers among the more than 230 total papers (and some 150 presentations) that carry his name. The *Science* paper cited in this article won the Newcomb-Cleveland Prize for best paper published in *Science* in 1980. He participated in more than 60 USGS research cruises, serving as chief or co-chief scientist for about half of them. Bill was a recipient of the U.S. Department of Interior's Meritorious Service Award (1986) and Distinguished Service Award (2002). He also received GSC's Michael J. Keen Medal (2003) for contributions to the field of marine geoscience and the Society for Sedimentary Geology's Francis Shepard Medal (2005) for excellence in marine geology. He was elected a Fellow of the American Geophysical Union in 2006.

Even though Bill, in 1974, stepped away from an academic career, fortunately for many of us, he never stopped being a mentor and teacher for generations of young scientists. For those who had a chance to work closely with him, Bill is best known for his unswerving scientific and personal generosity, his ongoing active collaboration with geologists from Italy and Canada, and his mentoring of more than 20 Stanford University and international graduate students.

Among his other interests, Bill had learned the fine points of wine making while in Menlo Park, and he, together with his good friends and fellow scientists Dave Scholl and Ed Clifton, was considered one of the best of the Survey's group of wine makers. His Gewurztraminer and Orange Muscat, both styled completely dry, are world-class wines. In 2007, the judges of California's most prestigious competition for the home wine maker awarded Bill's four entries with three silver medals and one gold medal. His 2007 Orange Muscat, which is outstandingly fruity, is to be entered in the 2008 competition.

In the last 4 years, Bill came full circle in his scientific career to work with Charlie Paull and colleagues at the Monterey Bay Aquarium Research Institute, using their autonomous underwater vehicles to continue his lifelong investigation of turbidite deposits.

Bill was a special person, a brilliant scientist, a great mentor, and an example of scientific rigor and honesty. He was a generous, kindly, and unassuming man within whom danced a most playful humor. Bill was a valued friend and he will be immensely missed.

—ANDREA FILDANI, Chevron Energy and Technology Company, San Ramon, Calif.; E-mail: andreafildani@chevron.com; DAVID W. SCHOLL, U.S. Geological Survey emeritus scientist and University of Alaska Fairbanks; and DOROTHY JEAN NORMARK

Honors

Lee Lou-Chuang has been appointed as Taiwan's Minister of the National Science Council. He has served as president of Taiwan's National Central University and of Taiwan's National Applied Research Laboratories. Lou-Chuang was an editor of the *Journal of Geophysical Research* from 2001 to 2005.

In Memoriam

Reginald Hardy Jr., 76, 22 January 2008, Tectonophysics, 1966

John Herman, 79, 5 April 2008, Aeronomy, 2002

William W. Kellogg, 90, 1 December 2007, Fellow, Atmospheric Sciences, 1949

Friedrich Schott, 60, 30 April 2008, Fellow, Physical Oceanography, 1982

Franklin F. Snyder, 97, 11 April 2008, Hydrology, 1935

Edward J. Walter, 93, 25 March 2008, Seismology, 1938

Alan T. Waterman Jr., 9 January 2008, Atmospheric Sciences, 1960

Jin Wu, 74, 14 January 2008, Ocean Sciences, 2005

Carl W. "Bill" Zanner, 59, 16 February 2008, Biogeosciences, 2002

GEOFIZZ

Goethe and the Aurora

Johann Wolfgang von Goethe (1749–1832) was deeply interested in many aspects of natural science, including geology and meteorology. Thus, it is not surprising that his works include frequent references to natural phenomena.

For example, the 1815 play *Des Epimenides Erwachen* ("Epimenides Awakes") includes some notes on comets and aurora, with the former described as "terrible portents."

Another interesting reference is the unfinished fragment "Die Zauberflöte, zweiter Teil" ("The Magic Flute, Part Two"), written in 1795–1796, several years after Mozart's death. After the Queen of the Night points out comets descending from the heavens amid constantly changing flames, the servant Monostatos and the choir reply, against a background of flaming aurora,

> Siehe! Die Kometen sie steigen hernieder,
> Wandelnde Flammen begegnen sich wieder,
> und von den Polen erhebt sich die Glut.

("Look! More comets descend and flickering flames occur again, springing up from the Poles like glowing embers.")

Undoubtedly, the "flickering flames" and the "glowing embers" refer to the aurora.

In addition, in his poem *Die Weltseele* ("Soul of the World"), Goethe makes further reference to comets. In the third verse of the poem, Goethe wrote about the comets moving through the universe and about the stars and planets that crossed their orbits.

Goethe also was known to discuss comets and other phenomena. On one occasion, 3 October 1828, Goethe told his secretary, Johann Peter Eckermann, that Karl August, the Grand Duke of Saxe-Weimar-Eisenach, Germany, had asked Goethe whether the tails of comets interacted with the Earth's atmosphere.

—WILFRIED SCHRÖDER, Geophysical Commission, Bremen-Rönnebeck, Germany

FORUM

Climate Science to Citizen Action: Energizing Nonformal Climate Science Education

Within the United States, public discourse on climate science and society's response to climate change are changing rapidly [*Nisbet and Myers*, 2007]. Awareness of the seriousness and urgency of the problem has been increasing, as has understanding of the complexity and scale of change in human behaviors and technologies that will be required to stabilize greenhouse gas emissions to mitigate climate change (see a Yale University/Gallup/ClearVision Institute poll at http://environment.yale.edu/news/Research/5310/american-opinions-on-global-warming-summary/). A tremendous opportunity exists to build upon this nascent awareness and enhance the degree to which U.S. citizens are informed about, and are ready to take action on, this defining challenge of the 21st century.

Although progress has been made in understanding the degree to which human activity contributes to climate change, disbelief and confusion persist and are frequently coupled with a tepid understanding of, and limited commitment to, changes in policy, technology, lifestyle, or behavior to reduce emissions. The scale of societal action required to stabilize greenhouse gases is enormous; to reach this scale, a deeper and more consistent public understanding of climate science and its implications for society is necessary. The term "climate science" used in this context reflects a multidisciplinary, integrated definition that includes technical, economic, and behavioral/social aspects associated with both the climate change problem and potential solutions.

Existing climate science educational resources are diffuse: Valuable information is dispersed among many different Web sites and organizations, and this information is of variable accuracy, quality, and accessibility. Given the urgency of the need for enhanced climate science understanding, it is critical to reduce redundancy and improve coordination of climate science education in at least three ways: (1) by unifying definitions and content of basic climate literacy, (2) by facilitating stronger and better networked coalitions to connect existing resources, and (3) by gathering and widely disseminating "best practices" in climate science education.

There should be aggressive support for, and expansion of, recent efforts in these three areas, including the collaboratively developed Climate Literacy Framework (spearheaded by the U.S. National Oceanic and Atmospheric Administration (NOAA) and which began to be distributed in March 2008) and the creation in mid-2007 of the multistakeholder Climate Literacy Network (information about both of these efforts is at http://www.climateliteracynow.org/). In addition, developing climate science networks to foster cross linking and sharing of valuable resources—including Web sites such as "Windows to the Universe" (http://www.windows.ucar.edu) and "Encyclopedia of Earth" (http://www.eoearth.org/), sponsored by the University Corporation for Atmospheric Research and the National Council on Science and the Environment, respectively—will enhance accessibility to, and use of, existing resources and will identify gaps and needs for additional resources.

Reaching a Diffuse Audience

While the diffusion of resources for climate change education is a significant, even daunting, challenge, a second area of diffusivity may prove even more difficult to surmount: the highly dispersed nature of the public audience. Approximately 20% of the U.S. population is enrolled in formal educational programs, i.e., classroom education at schools, colleges, and universities (see http://nces.ed.gov/programs/digest/d04/tables/dt04_394.asp). Thus, centralized, formal educational mechanisms, processes, and institutions do not reach 80% of the population, people whose decisions, actions, and attitudes have significant implications for society's response to climate change.

Given the urgency for taking action on climate change, there is not sufficient time to rely solely on the transfer of knowledge and understanding from the formal educational system to the population at large. The vast majority of the population must be reached through forums and mechanisms outside the traditional classroom. There needs to be a coordinated focus on nonformal education (organized education outside the K-16 system, i.e., workshops and other activities sponsored by community groups, nongovernmental organizations (NGOs), museums, and other organizations) and informal education (exposure to information through popular culture, mass media, and interactions with friends, family, and work colleagues).

The diffuse and heterogeneous nature of the audiences that could benefit from climate science education requires a coordi-

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nated, systematic, and energetic approach to nonformal climate science education. Different climate science information is compelling to different stakeholders. While learning about drought risk and the potential growing market for biofuels may be of interest to midwestern farmers, the potential for jobs in renewable energy and energy efficiency may be of critical interest to technical and vocational educators and to state and federal labor agencies. Pedagogical strategies that are responsive to diverse target audiences (including the use of localized examples of climate change impacts and the inclusion of specific potential financial implications of both climate change impacts and climate action initiatives) must be compiled and made available to the broad spectrum of individuals and organizations engaged in communicating climate science to different audiences.

In addition, there needs to be aggressive support for robust, formal classroom education on climate change science and its social implications, which should be leveraged for, supplemented by, and coordinated with nonformal and informal routes. To illustrate, a parallel may be made to the dual challenges of ensuring that new buildings are energy efficient and that existing buildings are retrofitted. New LEED-qualified (Leadership in Energy and Environmental Design) buildings often attract tremendous attention, but buildings that already exist consume roughly 40% of U.S. total energy use. Similarly, nonformal and informal education mechanisms should be deployed to address the climate literacy of the nonenrolled population, while simultaneously ensuring formal K-16 education for the next generation.

Need for Coordination

Thus, the drive for widespread climate literacy must confront diffusivity on two levels: widely dispersed educational resources, and highly diverse, minimally coordinated audiences. The climate education community cannot rely solely on traditional, centralized, formal channels. A nationally coordinated climate science education campaign is needed to achieve widespread public acknowledgment and understanding of climate change science and to enable society-wide action on this issue. This effort must address both formal and nonformal audiences, and it must develop both short- and long-term approaches in parallel. Strategic planning is critical to ensuring streamlined, efficient efforts in the long term; and the urgency of the climate change problem dictates that where possible, educators need to act now.

At the federal level, partnerships among the U.S. Climate Change Science Program, key federal agencies (National Science Foundation, Environmental Protection Agency, NASA, NOAA, and so forth), and a broad spectrum of nongovernmental partners are crucial for coordination and for ensuring multisectoral and diverse stakeholder input and engagement. A wide range of participants is needed in the development of a national-level strategic plan for climate science education that includes specific mechanisms for working with nongovernmental partners (the media, educators, corporations, foundations, and NGOs). This coordinated effort and strategic plan should include outreach to, and collaboration with, governmental and nongovernmental funding sources (i.e., private foundations) to initiate and support multidisciplinary research for benchmarking and assessing the effectiveness of existing climate change education programs and for identifying and evaluating promising integrative approaches ("best practices").

The imperative to energize nonformal climate science education has been recognized previously. For example, the proposal in 2006 by the Yale School of Forestry and Environmental Studies for a new consortium that focuses on communicating climate risks and opportunities identifies a similar need for coordinated, society-wide educational efforts to build support for acting on climate risks (see http://www.environment.yale.edu/climate/wp-content/uploads/2007/11/CommunicatingClimateRisk-Draft-1.pdf; see also *Abbasi* [2006]). The recent success of nationally coordinated climate change educational events—such as "Step It Up 2007" (a "day of action" launched by a small group of recent college graduates) and "Focus the Nation" (with more than 1900 colleges, universities, and other organizations sponsoring "teach-ins" on 31 January 2008)—demonstrate the potential of large-scale, nonformal initiatives to activate broad interest in climate issues.

The goal of education is to promote learning, and learning is a lifelong activity that can be fostered in many different forums in many diffuse ways. Energizing nonformal climate science education will expand the learning opportunities available to the U.S. public. Coordinated attention to the deployment of accurate, relevant climate science information in the full spectrum of educational approaches can increase citizens' ability to take the action required to confront the societal challenges of climate change.

Acknowledgments

This essay builds on outcomes from a workshop of climate educators at the National Council on Science and the Environment's 2008 annual meeting in Washington, D. C., in January 2008. Authors Jennie Stephens and Amanda Graham coconvened the workshop, "Diverse Perspectives on Climate Change Education: Integrating Across Boundaries," and they are indebted to participants for insights and resources.

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MEETINGS

Glacier and Permafrost Problems in High South Asia

International Workshop on Cryosphere and Hazards for Hindu Kush, Himalayas and Tibetan Plateau; Kathmandu, Nepal, 31 March to 2 April 2008

An outgrowth of prior conferences that had to be held separately for political reasons [*Bagla,* 2006a, 2006b], a 3-day workshop to discuss the impact of climate change on the glaciers and permafrost of high Asia hosted some 70 geoscientists from China, India, Nepal, Pakistan, and the United States and a few from Europe and Canada. The scientists concluded that a major need exists for better long-term monitoring of glaciers in the region using satellite imagery coupled with direct observations in the field. Also emphasized was the lack of cooperation or lack of sharing of essential hydrological information between the commonly militarily opposed countries in the area. Even within each country, agencies do not necessarily share data with other agencies or with university scientists. For example, a ludicrous situation was noted wherein it is easier to obtain high-resolution imagery and digital elevation models from scientists in opposing countries rather than domestically, where such data can be restricted or illegal to use. Such data hoarding potentially increases a population's risk because people who are trying to forecast hazardous droughts, floods, and landslides commonly cannot get appropriate information.

The workshop established six main conclusions, urging the governments of the Himalayan countries to facilitate data generation and sharing, and to identify at least one benchmark glacier in each country for long-term field-based study. Standardized methods should be developed and used for monitoring and assessing glaciers across the region to facilitate cross-border comparative analysis. Development of basin-wide water scenarios also should be encouraged for all the major water basins in the region as a series of transect studies from east to west.

The workshop brought together the best geoscientists for the region to brainstorm new ideas and procedures for obtaining information about the status and trends of snow and ice resources in high Asia. Additional analytical procedures and a volume of refereed papers from the conference are scheduled to be published in early 2009 in Elsevier's book series called *Developments in Earth Surface Processes*. Further follow-up collaborative projects are being defined, and people are being enlisted in research-proposal development through a structured e-mail consultation being run by Frans Neuman of the Mountain Forum (fneuman@mtnforum) and Greg Greenwood of the Mountain Research Initiative (MRI) (green@guib.unibe.ch).

The workshop, held at, and sponsored by, the International Centre for Integrated Mountain Development (ICIMOD) in Nepal, was also jointly organized by the University of Nebraska at Omaha with their Global Land Ice Measurements From Space Regional Center for Southwest Asia (Afghanistan and Pakistan), as well as the Monsoon Asia Integrated Regional Study (MAIRS) from China, the Institute for Development and Innovation (IDI) from Nepal, and the MRI in Switzerland. Workshop funding came from the U.S. National Science Foundation, the Lounsbery Foundation, and the Smithsonian Institution through its Indian Science and Technology Partnership.

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MEETING ANNOUNCEMENTS

■ 19–20 June 2008 **First ORFEUS Workshop on Waveform Inversion**, Utrecht, Netherlands. Sponsor: Observatories and Research Facilities for European Seismology (ORFEUS). (J. Trampert, Department of Earth Sciences, Utrecht University, P.O. Box 80021, Utrecht, Netherlands 3508 TA; Tel.: +31-0-30-253-5086; Fax: +31-0-30-253-2648; E-mail: trampert@geo.uu.nl; Web site: http://www.orfeus-eu.org/Announcements/workshop_utrecht/workshop_utrecht.htm)

The workshop's theme is waveform inversion. There will be presentations on various subjects covering studies of the Earth's structure and of seismic resources.

■ 8–10 September 2008 **Chapman Conference on Lakes and Reservoirs as Sentinels, Integrators, and Regulators of Climate Change**, Lake Tahoe, Nevada, USA. Sponsors: AGU; U.S. National Science Foundation; Miami University; others. (AGU Meetings Department, 2000 Florida Avenue, NW, Washington, DC 20009, USA; Tel.: +1-202-777-7333; Fax: +1-202-777-7385; E-mail: chapman-help@agu.org; Web site: http://www.agu.org/meetings/chapman/2008/dcall/)

The conference will examine the potentially important roles of lakes and reservoirs in global climate change, particularly regarding changes in the flux of energy, water, and carbon into, within, and out of lake basins, and the consequences for aquatic and terrestrial communities and ecosystems. While the conference will focus on science, the intention is to have the product be of substantial value to environmental managers and policy makers who deal with climate change issues.

■ 28 September to 2 October 2008 **The Clock and the Quantum: Time and Quantum Foundations**, Waterloo, Ontario, Canada. Sponsors: Perimeter Institute; Griffith University; University of Queensland; others. (K. Gillespie, 31 Caroline Street North, Waterloo, Ontario N2L 2Y5, Canada; Tel.: +1-519-569-7600 ext. 6061; E-mail: conferences@perimeterinstitute.ca; Web site: http://www.perimeterinstitute.ca/Events/The_Clock_and_the_Quantum)

The meeting's aim is to promote quantum foundations as a subject to be studied and researched in academia. The conference will focus on conceptual and technical issues concerning the role of time in quantum theory, including quantum correlations in time, probability and time, and time and quantum measurement. Abstract deadline is 15 July.

■ 5–9 October 2008 **SSSA-ASA-CSSA-GSA 2008 Joint Annual Meeting**, Houston, Texas, USA. Sponsors: Geological Society of America (GSA); American Society of Agronomy (ASA); Crop Science Society of America (CSSA); others. (L. Nelson, Soil Science Society of America, 677 South Segoe Road, Madison, WI 53711, USA; Tel.: +1-608-268-4963; E-mail: lnelson@soils.org; Web site: http://www.acsmeetings.org/)

This joint meeting will focus on areas of common interest among the organizations, including energy, water resources, education, and Earth systems. Abstract deadline is 3 June.

■ 18–23 October 2008 **New Challenges in Earthquake Dynamics: Observing and Modelling a Multi-Scale System**, Ötz Valley, Austria. Sponsors: European Science Foundation (ESF); Austrian Science Fund; Leopold-Franzens-Universität Innsbruck. (C. Orefice, Tel.: +32-0-2533-2023; Fax: +32-0-2538-8486; E-mail: corefice@esf.org; Web site: http://www.esf.org/conferences/08260)

The conference focuses on recent advances in earthquake physics. Topics include the observation of seismicity patterns, stochastic modeling of earthquake interactions, earthquake rupture in a heterogeneous crust, and statistical volcano seismology. Abstract deadline is 22 June.

■ 5–7 November 2008 **16th ACM SIGSPATIAL International Conference on Advances in Geographic Information Systems (ACM GIS 2008)**, Irvine, California, USA. Sponsors: Environmental Systems Research Institute; Oak Ridge National Laboratory; Microsoft. (H. Samet, Stanford University, Palo Alto, Calif., USA; E-mail: hjs@cs.umd.edu; Web site: http://acmgis08.cs.umn.edu/)

The conference provides a forum for original research contributions covering all conceptual, design, and implementation aspects of GIS, ranging from applications, user interface considerations, and visualization to storage management and indexing issues. Topics include cartography and geodesy, Earth observation, and spatial analysis and integration. Abstract deadline is 10 June.

■ 10–14 November 2008 **Chapman Conference on Universal Heliophysical Processes**, Savannah, Georgia, USA. Sponsors: AGU; others. (AGU Meetings Department, 2000 Florida Avenue, NW, Washington, DC 20009, USA; Tel.: +1-202-777-7333; Fax: +1-202-777-7385; E-mail: chapman-help@agu.org; Web site: http://www.agu.org/meetings/chapman/2008/gcall/)

The conference will reflect the approach to research described in the U.S. National Research Council's 2004 report, "Plasma Physics of the Local Cosmos." That report, available online, is organized into five categories: creation and annihilation of magnetic fields, formation of structures and transients, plasma interactions, explosive energy conversion, and energetic particle acceleration. Abstract deadline is 12 September.

Meetings

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Alerting the Public to Climate Change Impacts, Adaptation, and Mitigation

Fiftieth Anniversary of the Global Carbon Dioxide Record: A Symposium and Celebration; Kona, Hawaii, 28–30 November 2007

Atmospheric concentrations of carbon dioxide (CO_2) must be stabilized and reduced as quickly as possible to cut the risk of catastrophic climate change. Though reducing emissions to such a degree is a monumental task, it is not insurmountable. These were key points made by leaders in science, business, and government who converged near the Mauna Loa Observatory, Hawaii, to celebrate the fiftieth anniversary of the global atmospheric CO_2 record and to discuss the carbon cycle, climate change, and how to manage CO_2 emissions in the future.

What has made this record so valuable is the attention that scientists, inspired by Charles David Keeling of the Scripps Institution of Oceanography, who began taking measurements 50 years ago, have paid to accuracy, precision, and intercomparability in all aspects of the measurements.

A unique aspect of the conference was the mix of scientists from several disciplines, leading energy producers, and federal and state agency representatives who were present at the meeting. Their interactions fostered an exchange of information among largely different sectors involved in this issue. Much of the discussion coalesced into a few conclusions: that the growing atmospheric CO_2 concentration underscores the urgency of dealing with both emissions and a broad range of associated impacts, such as ocean acidification (discussed below); that we have the ability to begin reducing emissions substantially now; and that action has not been taken partly because the magnitude and urgency of the problem are not generally understood. The holistic nature of climate change impacts was illustrated by several presentations.

Significantly increased risks of flooding in major American cities like Boston and New York, decreased global food crops, and possible large releases of carbon from permafrost were among the problems addressed. Impacts of climate change in the world's oceans were examined, including observed decreases in pH of 0.1 and increases in temperature. Participants questioned whether calcareous organisms can survive a total pH decrease of 0.2 units, which corresponds to an atmosphere of approximately 500 parts per million CO_2.

Addressing a need for urgency, retired Vice Admiral Paul Gaffney explained that climate change poses a serious threat to national security and global stability. Richard Somerville of Scripps Institution of Oceanography advised that avoiding high-risk scenarios would require limiting the increase in global average temperature to 2°C over that of preindustrial times, reducing global greenhouse gas (GHG) emissions by at least 50% below their 1990 levels by the year 2050, and stabilizing GHG concentrations well below 450 parts per million.

Leaders of large utility companies expounded on both the challenges and opportunities presented by this problem. However, reasons to be hopeful abound. The world's energy demands, though growing quickly, can be met for the next 50 years using only existing technologies while avoiding a doubling of CO_2 levels compared with the preindustrial level, according to Rob Socolow of Princeton University. Carbon capture and storage, improved energy efficiency, photovoltaic power, concentrating solar power, wind energy, and nuclear energy all provide means of reducing GHG emissions. Business incentives, such as trading carbon credits, can also help.

In a nutshell, observations and projections of climate change are sobering. Meeting participants agreed that scientists need to explain clearly to the public what these observations and projections mean, and citizens have a responsibility to inform themselves about climate change. Further, current technologies can substantially meet the world's energy demands while reducing GHG emissions, but new technologies will be needed to meet growing global energy demands and still prevent the most dangerous degrees of climate change. For more information, visit http://www.co2conference.org.

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AGU JOURNAL HIGHLIGHTS

Monsoon surges trigger oceanic eddy formation and propagation in the lee of the Philippine Islands Oceanic eddies are common features that form in the wakes of islands around the world. Their motion is an important mechanism for distributing energy on local scales, which affects the supply of nutrients to different regions of the ocean. Prior studies on eddies suggest that they shed primarily through ocean flow instability formed by underwater topography. *Pullen et al.* hypothesized that wind forcing could also uniquely influence eddy detachment. Using studies of observational and modeled data, the authors identified monsoon surges that interacted with the island topography of the Philippines and triggered eddy formation in the South China Sea during January 2005. Further analysis of the modeled data revealed that wind jets and wakes in the lee of Mindoro and Luzon islands induced the generation and migration of a pair of counterrotating oceanic eddies, with propagation direction related to the orientation of winds during each of the surges. The authors suggest that monsoon surges likely represent a robust forcing mechanism for oceanic eddy formation and propagation in the South China Sea. (*Geophysical Research Letters*; doi:10.1029/2007GL033109, 2008)

Twentieth-century Antarctic air temperature and snowfall simulations: Comparing observations and climate models Establishing multidecadal, continental-scale records of near-surface air temperature (NSAT) and snowfall accumulation in Antarctica is important for understanding regional climate variability and the role Antarctic ice sheets play in global sea level change. Although generating such records is challenging due to Antarctica's sparse observational network, several recent studies have enhanced the observational data on NSAT and snowfall primarily during the past 50 years. *Monaghan et al.* compared these enhanced data with global climate models (GCMs), particularly those that support the Intergovernmental Panel on Climate Change's (IPCC) Fourth Assessment Report. They found that annual Antarctic snowfall accumulation trends in GCMs agree with observations during 1960–1990, and the sensitivity of snowfall to NSAT fluctuations is similar to that observed. However, longer-term NSAT trends (spanning 1880–1999) in the GCMs are about 2.5 to 5 times larger than observed, possibly due to the radiative impact of unrealistic increases in water vapor. Until these issues are resolved, IPCC projections of 21st-century Antarctic temperatures and snowfall amounts should be treated with caution. (*Geophysical Research Letters*, doi:10.1029/2007GL032630, 2008)

Source regions for windblown dust in East Antarctica over the past 800,000 years Understanding the geographic origin of continental windblown dust reaching Antarctica today and under different climate conditions is essential for tracking past changes in atmospheric circulation regimes. Scientists study windblown dust in Antarctic ice cores by determining the dust's strontium and neodymium isotope ratios, which are distinct for each source region and do not change while dust is being transported. Analyses of ice cores in central East Antarctica have revealed source regions for dust spanning the past 50,000 years. Noting that data from the Vostok and Dome-C ice cores span the past 800,000 years, *Delmonte et al.* analyzed ancient dust from these ice cores and found that their isotopic signatures indicate that during glacial periods between 350,000 and 800,000 years ago, dust originated mainly from South America. Similar to what is seen today, the data show an overall westerly wind circulation pattern that allows for dust from South America to reach Antarctica's interior. However, small but significant dissimilarity exists between old and recent glacial ages, suggesting that dust contributions from Patagonia were slightly reduced during ancient glaciations. (*Geophysical Research Letters*, doi:10.1029/2008GL033382, 2008)

—MOHI KUMAR, Staff Writer

BOOK REVIEWS

Methods and Tools for Drought Analysis and Management

Giuseppe Rossi, Teodora Vega, and Brunella Bonaccorso, Editors
Springer; 2007; xvi + 418 pp.; ISBN 978-1-4020-5923-0; $199.

Drought is an ambiguous concept. It is often difficult to tell when you are in a drought because of its slow, protracted nature and lack of news-grabbing impacts—such as water inundating communities or buildings burning—associated with other natural disasters. It is equally difficult to track the effect of drought on people, their livelihoods, and the environment because of the ubiquitous role that water plays in our world. As a result, we often wait until we are in the midst of a water crisis to seek ad hoc solutions, which can be costly, inefficient, and highly politicized.

To overcome the limitations of this crisis management approach, a risk management paradigm is being embraced by drought planners (along with planners dealing with other natural hazards). This paradigm focuses on implementing proactive strategies to reduce the likelihood of harm before a disaster occurs, instead of relying solely on reactive emergency actions during a crisis. In the case of drought, this includes developing drought monitoring and forecasting systems, implementing mitigation strategies to create more resilient systems, and creating preparedness plans that outline coordinated actions to be taken during a drought event.

Because of the ambiguous and complex nature of drought, the risk management paradigm is coming a bit later to the drought arena than to other hazards, and its application can be a complicated task. However, this book will help hydrometeorologists and water planners apply this paradigm to drought by providing specific examples of how risk management tools and methodologies can be used to quantitatively analyze drought and risk management options.

Methods and Tools for Drought Analysis and Management presents the results of research carried out by experts in the Mediterranean countries of Greece, Italy, Portugal, and Spain within the fields of hydrometeorological monitoring and water supply systems analysis and management. The purpose of the research was to investigate and propose common methodologies for assessing drought and potential management options in the region. The research was part of the SEDEMED (Sécheresse et Désertification dans le Bassin Méditerranéen, or Drought and Desertification in the Mediterranean Basin) and SEDEMED II projects funded by the European Commission from 2003 to 2006.

The book comprises five sections written by researchers involved in the SEDEMED and SEDEMED II projects: (1) drought monitoring and forecasting methods, with a special emphasis on the Standardized Precipitation Index; (2) the use of agrometeorological indices and remote sensing in drought assessment; (3) water quantity and quality monitoring and management, including simulation and optimization modeling for evaluating alternative management scenarios under drought conditions; (4) groundwater monitoring and management under drought conditions, including saltwater intrusion; and (5) assessing drought impacts and mitigation measures in agricultural and urban areas.

In addition to including topics a person would expect to see in a typical drought-related work, each section also provides unique information that has been neglected elsewhere in the literature, which adds to the appeal of the book. For example, other sources discuss use of the Standardized Precipitation Index, but this book discusses its use at different scales and its potential for forecasting drought conditions. Similarly, when presenting the agrometeorological indices, the authors discuss not only the indices' calculations and applications but also how the information could be incorporated into decision-support Web sites for use by decision makers.

Furthermore, the water management section provides two chapters related to water quality and drought, and another section is devoted entirely to groundwater. Both of these topics are often neglected in the drought literature. Finally, in the last section, the authors discuss how to assess drought risk. Instead of merely providing the typical list of potential risk reduction measures that could be implemented, the authors also propose how to quantitatively assess drought risk and risk management options, which more closely resembles analyses conducted for other natural hazards.

Although the book provides a wealth of examples of how drought risk and management options can be evaluated, many of the proposed strategies will require a good deal of data collection and processing. The equipment, skills, and time necessary to accomplish these tasks may limit their widespread applicability in some cases. Therefore, it seems that the primary target audience for this book would be researchers and technicians working in heavily monitored and managed agricultural and urban systems. Likewise, the price of this book ($199) may be limiting for some potential users who would benefit from its contents.

Overall, even though the studies and examples have been tailored to the northern Mediterranean region, this is a good book for planners and technicians interested in applying new techniques to assess drought and potential management strategies. The book, which is not for the statistically or methodologically faint-of-heart, provides important insight into taking drought risk assessment and management to the next quantitative step.

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Book Reviews

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Discovering the Solar System, Second Edition

Barrie W. Jones
John Wiley; 2007; xvi + 453 pp.; ISBN 978-0-470-01830-9; $180

The solar system, notably its origin and evolution, has intrigued astronomers for centuries. Since the advent of the space age, much more has become known about the bodies that constitute the solar system. Space-based telescopes have become available, and orbiting spacecraft and landers have enabled an examination of these bodies at close range and at previously inaccessible wavelengths. This accumulation of observational data continues, and we expect to see a surge, given the recent interest in planetary exploration from space agencies around the world.

This vast amount of data, coupled with the inherent multidisciplinary nature of solar system research, makes it challenging for a theoretically self-consistent understanding to be reached. It is therefore equally challenging for any textbook to provide a comprehensive, yet comprehensible, account of the solar system for those who are approaching the subject for the first time. In this regard, *Discovering the Solar System* has done an excellent job.

The book is well structured around themes, which makes it coherent and thus more accessible for those new to the topic. The book is divided into two parts. The first part, comprising chapters 1–3, presents an overview of the solar system, examining its origin and giving an account of small bodies: asteroids, comets, and meteorites. These chapters establish a context in which one may consider the origin and evolution of the planets and their satellites, to which the second part of the book is devoted.

For the planets and their satellites, the author examines their interiors, surfaces, and atmospheres in three subsections. Each subsection starts with a chapter discussing general principles, based on which the processes occurring in regions of interest may be understood. These general principles are followed by discussions of individual bodies, with constant referrals to the general principles previously introduced and to the theory of the origin of the solar system. As a result, before the reader finishes the book, he or she will have become familiar with some of the general laws and their applications, and with the evolutionary path of the solar system.

In addition to its logical structure, the book is also commendable in its presentation style. From the outset, the reader is assumed to possess an amount of background knowledge in geology, chemistry, and physics equivalent to no more than that of a first-year university student. The author then presents information step by step in the text and avoids calculus altogether. A series of "stop and think" questions is designed to help the reader gain some hands-on experience in applying the acquired knowledge to explain what has been observed, or even to predict what has yet to be observed, in the solar system. The tables, diagrams, and photographs, which are abundant and of high quality, make the text very readable. Moreover, wherever the reader needs help with what appears unfamiliar, the glossary comes to the rescue. The reader may also need to turn to the answers to questions posed at the end of some sections, although he or she is urged to think about these questions beforehand.

In short, this book provides an up-to-date and comprehensive account of what is known about the present and the past of the solar system in a reader-friendly manner. Those approaching the subject for the first time will certainly find the book worth reading. Those who have already acquired more knowledge than assumed by the author will gain a better and deeper understanding from the book.

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NEW BOOKS

This column lists recently published books that have been received by Eos.

A Century of Ideas: Perspectives from Leading Scientists of the 20th Century, B. G. Sidharth (Ed.), Springer, 2008, ISBN 978-1-4020-4359-8, $129.

Cloud-Resolving Modeling of Convective Processes, Shouting Gao and Xiaofan Li, Springer, 2008, ISBN 978-1-4020-8275-7, $149.

Computational Geometry: Algorithms and Applications, Third Edition, Mark de Berg et al., Springer, 2008, ISBN 978-3-540-77973-5, $49.95

Coral Reefs of the USA, Bernhard M. Riegl and Richard E. Dodge (Eds.), Springer, 2008, ISBN 978-1-4020-6846-1, $169.

Design and Construction of Tunnels: Analysis of Controlled Deformation in Rock and Soils (ADECO-RS), Pietro Lunardi, Springer, 2008, ISBN 978-3-540-73874-9, $139.

Earthquake Monitoring and Seismic Hazard Mitigation in Balkan Countries, Eystein S. Husebye (Ed.), Springer, 2008, ISBN 978-1-402-06813-3, $179.95

Food and Water Security, U. Aswathanarayana (Ed.), Taylor and Francis, 2008, ISBN 978-0-415-44018-9, $129.95

Fundamentals of Physical Volcanology, Elisabeth A. Parfitt and Lionel Wilson, Blackwell Publishing, 2008, ISBN 978-0-632-05443-5, $70.

The Geodynamics of the Aegean and Anatolia, T. Taymaz et al. (Eds.), The Geological Society, 2007, ISBN 978-1-86239-239-7, $170.

IFAE 2007: Italian Meeting on High Energy Physics, Gianpaolo Carlino et al. (Eds.), Springer, 2008, ISBN 978-8-847-00746-8, $89.95

Modeling Solar Radiation at the Earth Surface, Viorel Badescu (Ed.), Springer, 2008, ISBN 978-3-540-77454-9, $139.

A Pan-Chromatic View of Clusters of Galaxies and the Large-Scale Structure, Manolis Plionis et al. (Eds.), Springer, 2008, ISBN 978-1-4020-6940-6, $89.95

Pre-Columbian Landscapes of Creation and Origin, John Edward Staller (Ed.), Springer, 2008, ISBN 978-0-387-76909-7, $99.

Remote Sensing of the European Seas, V. Barale and M. Gade (Eds.), Springer, 2008, ISBN 978-1-4020-6771-6, $169.

Roadside Geology of Florida, Jonathan R. Bryan et al., Mountain Press Publishing, 2008, ISBN 978-0-87842-542-6, $26.

Solar System Astrophysics: Background Science and the Inner Solar System, Eugene F. Milone and William J. F. Wilson, Springer, 2008, ISBN 978-0-387-73154-4, $79.95

Space Sciences Series of ISSI: Mercury, André Balogh et al. (Eds.), Springer, 2008, ISBN 978-0-387-77538-8, $179.

Treatment System Hydraulics, John Bergendahl, Ph.D., P.E., ASCE Press, 2008, ISBN 978-0-7844-0919-0, $100.

CLASSIFIED

POSITIONS AVAILABLE

Atmospheric Sciences

Hydrometeorological Research Position. The University Corporation for Atmospheric Research Visiting Scientist Programs is recruiting a visiting scientist to work at the Hydrometeorological Design Studies Center (HDSC) of the National Weather Service in Silver Spring, Maryland. HDSC is responsible for de-facto U.S. standards for precipitation frequency.

The position will perform the following:
• Research and assist in recommending, developing, and establishing national policies or techniques for statistical analysis of precipitation data.
• Author technical reports, scientific publications, and present papers at seminars and scientific meetings.
• Perform tasks needed to develop precipitation frequency estimates, such as data collection, statistical modeling and interpretation of results.

Applicants should have a PhD in engineering with specialization in hydrology or hydrometeorology or an equivalent combination of education and experience. Applicants must have advanced knowledge and experience in statistical methods relevant to precipitation and/or flood frequency analysis, such as, statistical treatment of hydrometeorological data, frequency analysis of extreme events, analysis and modeling of time series, and geostatistics.

Visitors to HDSC will be employees of the University Corporation for Atmospheric Research (UCAR) and receive excellent benefits. The position will remain open until filled.

Applications may be submitted in electronic form and preferable .pdf via email attachments sent to vsp@ucar.edu.

For further information please call (303) 497-8634 or visit www.vsp.ucar.edu.

Postdoctoral Associate on Aerosol Nucleation: Two Immediate Positions. Two postdoctoral positions for aerosol nucleation studies are immediately available at Kent State University Atmospheric Chemistry Group (http://www.personal.kent.edu/~slee19/). The central responsibilities include (1) conducting aerosol nucleation experiments using chemical ionization mass spectrometers, (2) building nucleation experiment setup, (3) developing mass spectrometry to detect organic compounds, (4) conducting atmospheric observations of aerosol sizes and aerosol precursors, and (5) presenting and publishing scientific findings in peer reviewed journals. Background in atmospheric chemistry/physics and strong experimental and communication skills are required, and experiences with mass spectrometry and aerosol instruments are preferred. Ability to work in a team, as well as independently, is essential. These research projects are sponsored by National Science Foundation (NSF) and National Oceanic and Atmospheric Administration (NOAA). The postdoc positions are yearly renewable up to three years depending on the accomplishment. Please contact Professor Shanhu Lee (slee19@kent.edu, 330 672 3905) for more information. To apply, please send your CV, a brief statement of scientific findings and research interests, electronic copy of publications and three references. KSU is an Equal Opportunity, Affirmative Action Employer.

Postdoctoral Positions in Environmental Chemistry. Candidates having backgrounds in aerosol chemistry and characterization are particularly sought. Applicants should send by email a curriculum vitae as a single PDF file to scot_martin@harvard.edu. Website: www.deas.harvard.edu/environmental-chemistry. Applications will be reviewed beginning July 15, although applications received after this time may still be considered. Harvard University is an equal opportunity/affirmative action employer.

Hydrology

Post-Doctoral Position in Computational SubSurface Flow and Transport. The Integrated Multiphase Environmental Systems (IMPES) Laboratory in the Department of Civil & Environmental Engineering at Tufts University invites applications for a Postdoctoral Associate in Computational Subsurface Flow and Transport. This is a full-time, 2 year position with potential for reappointment available. Successful applicants must 1) hold a Ph.D. or equivalent degree in engineering, applied mathematics, or a related field; 2) have experience with numerical methods and modeling processes occurring in porous media; and 3) have capability to program in Fortran and Matlab.

Applicants are encouraged to submit his/her curriculum vitae, a statement of research interests, and contact information for three references to Professor Linda M. Abriola: linda.abriola@tufts.edu. The review process will begin immediately for a summer or fall 2008 appointment. Tufts University is an Affirmative Action/Equal Opportunity employer. Women and members of underrepresented groups are strongly encouraged to apply.

Post-Doctoral Position in Hydrology and Remote Sensing. The USDA, Agricultural Research Service (ARS), Animal and Natural Resources Institute's Hydrology and Remote Sensing Laboratory, in Beltsville, Maryland, is seeking a Postdoctoral Research Associate, Research Physical Scientist, for a two year appointment. Recent Ph.D. is required. Salary is commensurate with experience and can range between $58,206 to $90,698 per annum, plus benefits. Citizenship restrictions apply. Refer to announcement RA-08-022H at: http://www.afm.ars.usda.gov/divisions/hrd/hrdhomepage/vacancy/pd962.html to obtain the full text announcement, complete application instructions, and further information on Postdoctoral Research Associate positions. The incumbent will develop and apply remote sensing and data assimilation techniques to enhance the calculation of water balance storage and flux terms within a hydrologic model. Recently developed techniques will be applied that assess the added utility of assimilating remote sensing data into a regional water balance model relative to a baseline case of no constraint using remote sensing. Research will be conducted at a range of spatial scales with an underlying emphasis on regionalizing water balance calculations required for large-scale drought monitoring and/or water quality assessments. To apply, please send a brief description of research interests, a resume, and the names of two references to Dr. Wade Crow, USDA/ARS/ANRI/HRSL Bldg. 007, Room 104,

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Beltsville, MD 20705 or e-mail (wade.crow@ars.usda.gov) before July 1, 2008. USDA/ARS is an equal opportunity provider and employer.

Water Resources Director. The Water Resources Research Institute of The University of North Carolina invites nominations and applications for the position of Director. The Director manages a statewide research program that is open to all public and private institutions of higher education in North Carolina. Please refer to website: http://www.ncsu.edu/wrri/directorsearch.html

EOE/AA. In addition, NC State welcomes all applicants without regard to sexual orientation.

Ocean Sciences

Gas Geochemist-Assistant, Associate or Senior Scientist. The Marine Chemistry & Geochemistry Department invites applications for a tenure track position at the level of Assistant, Associate or Senior Scientist in the field of Gas Geochemistry. Areas of interest include use of inert and reactive gases as tracers of physical and biogeochemical processes including water mass movement, biological productivity, and the exchange of gases between the atmosphere and the ocean and/or the cryosphere.

Candidates with interest in strong sea-going research programs, and in the development of novel measurement techniques are particularly encouraged to apply.

WHOI is a private non-profit research organization that offers exceptional research and educational opportunities. The selected individual(s) would have the opportunity to work closely with WHOI scientists and engineers carrying out research in the fields of chemical and biological oceanography, upper ocean physics and marine meteorology. Information regarding on-going research at WHOI can be found at www.whoi.edu.

The successful applicant is expected to have a strong interest in collaborative research, seek funding to establish and sustain a productive research program, and contribute to graduate education within the MIT-WHOI Joint Program in Oceanography/Applied Ocean Science and Engineering.

The candidate should submit a current CV, a short (1-3 page) Research Statement, and the names of potential references along with her/his on-line application. Review of applications will begin on July 1, 2008. The level of the appointment will be based on credentials and experience. This is a regular full time position and is eligible for benefits.

For more information or to apply, please visit our Career Center: http://jobs.whoi.edu.

WHOI is an Affirmative Action/Equal Opportunity Employer, M/F/D/V. Applicants are reviewed confidentially.

Solid Earth Geophysics

Faculty Positions at Department of Geosciences, National Taiwan University. The Department of Geosciences at NTU is seeking active scientists to fill one to two faculty positions starting from 1st February, 2009 or 1st August, 2009. The positions are open to all fields in geosciences, but the following fields will receive more favored consideration: (1) Rock mechanics, (2) Surface processes, (3) Neotectonics, (4) Geophysics, (5) Remote sensing, (6) Global changes and (7) Geo-resources. Applicants are requested to submit the following documents: CV, list of publications, three to five reprints of refereed publications (one of which shall be designated as representative paper and must be published after 1st February, 2006), plans for teaching and research, and names of three potential referees to Professor Hongey Chen, Department of Geosciences, National Taiwan University, No. 1, Sec. 4, Roosevelt Rd., Taipei 106, Taiwan. Also, please email the above material to Professor Tsanyao Frank Yang, the Convener of the searching committee, at tyyang@ntu.edu.tw.

Deadline for application: 31st August, 2008. Web site: http://www.gl.ntu.edu.tw/

Two Postdoctoral Positions in Applied, Engineering, and Environmental Geophysics. The Applied and Environmental Geophysics (AUG) Group at ETH (Swiss Federal Institute of Technology) in Zurich has openings for two gifted young geophysicist at the post-doctoral level. The appointments will be for an initial period of two years. Subject to good performance and funding, one of the positions may be extended for an additional two years. We seek excellent scientists who have expertise and interests in theoretical and/or practical aspects of applied, engineering, and environmental geophysics (including hydrogeophysics). The successful candidates will be expected to: (i) initiate and conduct their own research projects, (ii) co-supervise undergraduate- and graduate-level thesis projects, and (iii) contribute to the teaching of applied, engineering and environmental geophysics courses. Furthermore, they will participate in the teaching of a recently launched joint MSc degree in Applied Geophysics with colleagues at the Technical University of Delft (TUD) and the Aachen University of Technology (RWTH). Good knowledge of English is essential and it would be an advantage, although not essential, to have a working understanding of German. At the time of appointment, the successful candidate must have a doctoral degree in geophysics or related subject. Information on AUG's research activities can be found at http://www.aug.geophys.ethz.ch/ and the joint MSc degree at http://www.idealeague.org/geophysics/.

To apply please email your resume together with the names, telephone numbers, and email addresses of two referees to Professor Alan G. Green (green@aug.ig.erdw.ethz.ch). Deadline for receipt of applications is June 30, 2008.

Interdisciplinary/Other

Geochemical Hydrogeology, Assistant Professor, Portland State University. The Department of Geology, Portland State University invites applications for a tenure-track Assistant Professor position in Geochemical Hydrogeology beginning September 16, 2008. This hire is part of a University initiative to enhance the science-perspective in the nationally renowned Freshman Inquiry program of University Studies. The successful candidate will be an active member of the University Studies Program and will teach the Freshman Inquiry class. Teaching and research in hydrogeology with an emphasis in geochemistry is an important contribution to the department, the university's effort in the water sciences, and to collaborations with our local US Geological Survey office. Qualifications for the position included a doctoral degree at the time of hire, a record of scholarly activities including publications in peer-review literature and a record of obtaining outside funding. We will consider applications to the broader subject of geochemical hydrology but our intent is to hire someone with interests and experience in hydrogeology. For application details, please see www.geology.pdx.edu Portland State University is an Affirmative Action, Equal Opportunity institution and, in keeping with the President's diversity initiative, welcomes applications from diverse candidates. The successful candidate will make significant and balanced contributions to teaching, research, and service, including development of a nationally respected externally funded research program.

Multiple Remote Sensing Positions. IMSG is looking for several data analysts and supporting scientists at different levels to support the NOAA/NESDIS Center for Satellite Applications and Research in Camp Springs, MD (soon to be relocated to College Park). The positions require formal training or experience in several areas including space weather, or the remote sensing of land/atmosphere to support the growing needs of NOAA's next generation geostationary and polar orbiting programs, as well as international collaboration initiatives. BS, MS, or Ph.D. degrees in astronomy, atmospheric science, physics, remote sensing, or earth sciences, and skills in satellite data processing and analysis using IDL and/or FORTRAN/C are required. Excellent communication skills including writing and presentation are a major plus. These positions will support leading NOAA scientists in the areas of cal/val, algorithm development, and system development for generating fundamental climate data records and various operational remote sensing data products. Detailed position descriptions are available at http://www.imsg.com. To apply, please email resume to jobs@imsg.com and CC Dr. Le Jiang at jiangl@imsg.com.

Opportunity in Aquatic and Marine Environmental Modeling. The Environmental Laboratory of the U.S. Army Engineer Research and Development Center, Vicksburg, MS, is seeking an individual with expertise in modeling aquatic and marine environmental systems. Candidates should have a PhD in environmental science, engineering, or related field and should be capable of applying multi-dimensional, mass-conservation based models that incorporate aspects of aquatic physics, chemistry, and biology. This position provides opportunity to work with established experts in the field and to collaborate with specialists in other fields to develop solutions to complex environmental issues of national and international importance. US citizenship is required. This is a full time, permanent DB04 position (GS12-GS14), and starting salary will depend on qualifications and experience. The US Army Engineer Research and Development Center is an Equal Opportunity Employer.

Candidates can send resumes to: Pamela.K.Corulla@usace.army.mil or contact Ms. Corulla by phone at 601-634-3861.

Post-Doctoral Research Associate in Global Electromagnetic Induction. The College of Oceanic and Atmospheric Sciences (COAS) at Oregon State University (OSU) invites applications for a full-time position as a Postdoctoral Research Associate. We seek a colleague to join an active electromagnetic induction research group, working on novel methods for data processing, inversion, and improved characterization of external magnetic field variations, with applications to studies of large scale geodynamic processes. The focus of this project is on development of improved data-based models of external magnetic field variations, with particular application to studies of deep mantle electrical conductivity. The research will involve development of novel data processing and inversion methods, and application to observatory and satellite geomagnetic data. The successful applicant will interact with other members of the team developing and applying 3D inversion codes for mantle electrical conductivity studies, and participate in efforts to develop methodologies for joint inversion for external source spatial structure and 3D Earth conductivity. There will also be opportunities for collaboration with other researchers involved in the project on other aspects of satellite magnetic field studies. The position requires a PhD in geophysics, in applied mathematics, physics or a related physical science.

Computer programming skills, with significant experience in either analysis of large data sets or numerical modeling, and good oral and written communications skills are also required. Preference will be given to candidates with some background in electromagnetic geophysics, geomagnetism, or ionospheric/magnetospheric physics. Previous experience working with geophysical inversion or data assimilation methods is also highly desirable.

To access application instructions, go to http://oregonstate.edu/jobs, posting 0002551 and for the position announcement, go to http://www.coas.oregonstate.edu/. Questions may be directed to Dr. Gary Egbert (541)737-2947 or egbert@coas.oregonstate.edu. Closing date is 7/1/08. OSU is an AA/EOE.

STUDENT OPPORTUNITIES

PhD Opportunities in Auckland, New Zealand. The School of Geography, Geology and Environmental Science at the University of Auckland, New Zealand, invites applications for 3 PhD positions: Petrology of the Auckland Volcanic Field; Physical controls on monogenetic basaltic volcanism; and Quaternary crypto-tephra study of sediments in Auckland maars. Applications due 30 June 2008; expected start date Dec 08. Please visit www.geology.auckland.ac.nz/postgraduate/scholarships

PhD/MS Research Assistantship in Hydrology/Computational Fluid Dynamics, Florida International University, Miami. Collaborative research with USGS will apply geostatistical analysis for virtual aquifer simulation based on karst data sets, including optical borehole images. Lattice Boltzmann 3-D flow simulations will be conducted in a parallel computing environment to evaluate hydraulic conductivity distributions and non-Darcian flow effects. FIU requires verbal+quantitative GRE >1000 for MS students and >1120 for PhD. TOEFL required (>550 or >230 computerized) for non-native English speakers. Strong quantitative and computer skills required. FIU offers competitive salary ($28,000) and an exceptional environment. Contact Dr. Mike Sukop at sukopm@fiu.edu for further information.

The University of Chicago, Center for Advanced Radiation Sources (CARS)
Research Beamline Scientist (Job Requisition 079054)

General Summary: This is a full-time, benefits-eligible University of Chicago position as a Research Beamline Scientist at the Advanced Photon Source (APS), Argonne National Laboratory, Argonne, Illinois. The successful candidate will provide support for scientific users from the geochemistry and environmental science communities who conduct research using the GeoSoilEnviroCARS synchrotron beamlines at the APS. The beamline scientist will also participate in core and collaborative research and will be involved in the development of new techniques for collection and analysis of synchrotron data and in the maintenance and development of beamline instrumentation.

Candidate must have synchrotron research experience using multiple synchrotron X-ray techniques, in particular X-ray absorption spectroscopy and X-ray fluorescence imaging but also X-ray surface scattering, X-ray tomography, and/or X-ray diffraction along with experience in applying such techniques to scientific problems in geochemistry and environmental science. Considerable experience with the operation of synchrotron beamlines and demonstrated skill in analyzing and interpreting these data are highly desirable. Skills in fostering successful scientific collaborations, communicating, and publishing research results are necessary.

Qualifications: Required are a Ph.D. in geology, environmental science, chemistry, physics, or a related field; a minimum of 2 years postdoctoral experience applying synchrotron X-ray techniques in earth and environmental science research; excellent relevant computer skills; ability to work well as a team member and independently; good organizational, verbal, and written communication skills. Ability to work in an environment with strict safety regulations and satisfy the requirements for access to Argonne National Laboratory necessary. A resume, research statement, reference contact information, and a cover letter are required to be considered for this position.

Interested parties must apply on-line at https://jobopportunities.uchicago.edu.
The University of Chicago is an Affirmative Action / Equal Opportunity Employer.